Title: Buffers in Fruit Drinks

Brief Overview:

Human blood is buffered with a pH of about 7.4. If the pH of blood were to vary by 0.2, a person could become seriously ill. Buffers resist changes in pH because they contain an acidic species to neutralize hydroxide (OH 1) ions and a basic one to neutralize hydrogen (H+1) ions. In this activity several brands of commercial fruit drinks will be titrated to compare their effectiveness as buffers. Students will be given a specific volume of each drink and a known concentration of sodium hydroxide. They will titrate the drink with hydroxide solution and monitor the pH with a pH electrode. Students then will collect data on pH versus sodium hydroxide volume for each drink with the TI-83 and CBL. Using the collected data and the TI-83, they will analyze the experimental data and pooled class data. They also will compare the buffered drinks with unbuffered citric acid.

NCTM 2000 Principles for School Mathematics:

- **Equity:** *Excellence in mathematics education requires equity - high expectations and strong support for all students.*

- **Curriculum:** *A curriculum is more than a collection of activities: it must be coherent, focused on important mathematics, and well articulated across the grades.*

- **Teaching:** *Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well.*

- **Learning:** *Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge.*

- **Assessment:** *Assessment should support the learning of important mathematics and furnish useful information to both teachers and students.*

- **Technology:** *Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning.*

Links to NCTM 2000 Standards:

- **Content Standards**

Number and Operations
Students will understand the importance of significant digits, precision, and estimation.

Measurement
Students will employ a variety of measuring techniques and tools. Proper units and labeling will be stressed.

Data Analysis and Probability
Students will collect and analyze data using the TI-83 calculator and the Calculator Based Laboratory(CBL). Data can be transferred between the TI-83 and a desktop computer for enhanced analyzes and printing, if desired. Students will be expected to draw conclusions from their analyzes and to extrapolate to situations not observed.

- **Process Standards**

  Problem Solving
  Students will learn the appropriate methods involved in, and the uses, of experimentally gathered data and pooled class data. They will develop strategies to interpret the data collected and will use their observations to generalize solutions and as an aid in predicting future outcomes.

  Reasoning and Proof
  Students will be asked to make conjectures based on their individually data collected. They will use pooled class data and class observations to validate their conjectures. Students will use reasoning to analyze differences and similarities in pooled data.

  Communication
  Students will work in teams to collect, organize, pool, and analyze their data. Whole class discussions and data pooling will be an integral part of the lesson. The importance of communicating one's solution processes, both orally and in writing, will be emphasized throughout.

  Connections
  Students will explore the relationships between science and mathematics through experimental collection, statistical analyses, and visual representation of scientific data. A variety of mathematical concepts, topics, and techniques will be encountered throughout the unit.

  Representation
  Students will use tabular, graphical, and functional representations of data and examine their connections. Students will learn the appropriate uses of each representational method and examine their inherent strengths and weaknesses.

Links to Maryland High School Mathematics Core Learning Goals:

Functions and Algebra

- **1.1**
  Students will analyze patterns and functional relationships using the language of mathematics and appropriate technology. (**1.1.1, 1.1.2**)

- **1.2**
  Students will model and interpret real-world situations, using the language of mathematics and appropriate technology. (**1.2.1**)

Data Analysis and Probability

- **3.1**
  Students will collect, organize, analyze, and present data.(**3.1.1, 3.1.2, 3.1.3**)

- **3.2**
  Students will apply the basic concepts of statistics and probability to predict possible outcomes of real-world situations. (**3.2.1, 3.2.2**)

Links to National Science Education Standards:

- **Unifying Concepts and Processes**
  Students will demonstrate an understanding of chemical systems, procedural order, and organization of procedures and data. They will gather evidence of a physical process, model the results mathematically, and use both to explain the reaction.

- **Science as Inquiry**
  Students will develop abilities in scientific inquiry to include: data collection, constructing and reading graphs, statistical analysis, and the care/handling of lab equipment.

- **Physical Science**
  Students will learn about the structure of atoms and the structure and properties of matter.

- **Science and Technology**
  Students will develop an understanding of science and technology and will demonstrate an ability in both.

Links to Maryland High School Science Core Learning Goals:

Concepts of Chemistry

- **4.1**
  Students will explain how the observation of the property of matter forms the basis for understanding its structure and changes in its structure.

- **4.2**
  Students will explain that all matter has structure, and the structure serves as the basis for the properties of, and the changes in, matter. (**4.2.1, 4.2.3, 4.2.4)**

- **4.6**
  Students will show that connections exist both within the various fields of science and among science and other disciplines including mathematics, social studies, language arts, fine arts, and technology. (**4.6.2**)

Grade/Level:

Grades 10(Honors) - 12, Algebra I, Algebra II, Pre-Calculus, Chemistry

Duration/Length:

This activity should take two days. The time is based on 45-50 minute periods.

Prerequisite Knowledge:

Students should have working knowledge of the following skills:

- Using the CBL
- Using TI-83 calculator
- Basic statistics (e.g., mean, median, mode)
- Data collection
- Construction and reading of a graph
- Acid/base chemistry as it relates to buffers
- Care and handling of lab equipment
- Calculating moles from concentration data

Student Outcomes:

Students will:

- brainstorm methods for data collection and analysis.
- work cooperatively in groups to collect and organize data using the TI-83, CBL, and pH probe.

- produce graphs of collected data using the TI-83.
- analyze data with the TI-83.
- participate in a discussion on observed results.
- relate experimental results to real-world situations.

Materials/Resources/Printed Materials:

- CBL System
- TI-83 graphing calculator with CHEMBIO software
- Vernier pH Amplifier and pH electrode
- Vernier adapter cable
- TI-Graph Link
- .01 M Citric acid
- Three fruit drinks containing citric acid (e.g. lemonade)
- 0.10 M NaOH solution
- 50 mL buret with ring stand
- 2 Utility clamps
- 100 mL graduated cylinder
- Wash bottle with distilled water
- Magnetic stirrer (optional)
- Eye protecting goggles

Development/Procedures

1. Wear goggles.

2. Use a graduated cylinder to measure out 40 mL of the lemonade drink and 60 mL of distilled water into a 250 mL beaker.

3. Place the beaker on a magnetic stirrer and add a stirring bar. If no magnetic stirrer is available, you will need to stir with a stirring rod during the titration.

4. Prepare the pH system for data collection.

    - Plug the pH amplifier into the adapter cable in Channel 1 of the CBL. The pH electrode is already connected to the pH amplifier.
    - Use the link cable to connect the CBL to the TI Graphing Calculator. **Firmly** press in the cable ends.

5. Set up the ring stand.

6. Use a utility clamp to suspend a pH electrode on the ring stand. Position the pH electrode in the lemonade mixture and adjust its position so that the stirring bar does not strike it.

7. Obtain a 50 mL buret and rinse the buret with 5 mL of the 0.1 M NaOH solution. **CAUTION:** Sodium hydroxide solution is caustic. Avoid spilling on skin or clothing. Dispose of the rinse solution as directed by your teacher.
    Attach the utility clamp to the ring stand as illustrated. Fill the buret a little above the 0.00 mL level of the buret with 0.10 M NaOH solution. Drain a small amount of the solution so it fills the buret tip and your buret reads 0.00 mL. Record the concentration of the NaOH solution in your data table.

8. Turn on the CBL and the calculator. Start the CHEMBIO program and proceed to the MAIN MENU.

9. Set up the system for measurement.

- Select 1 SET UP PROBES.
- Enter 1 as the number of probes.
- Select 2 PH
- Enter 1 as the channel number
- Select 1 USE STORED

10. Set up for data collection.

- Select 2 COLLECT DATA.
- Select 3 TRIGGER/PROMPT. Follow the directions on the calculator screen to allow the system to warm up. Press *ENTER*.

11. Once the pH stabilizes press TRIGGER on the CBL . Enter 0 (buret reading in mL) in the TI calculator. This is the first data pair for this experiment before titrating.

12. You now are ready to begin the titration. One person should manipulate the buret and give the reading to another person operating the calculator and entering volumes.

13. Select 1 MORE DATA to collect another data pair. Add 2.0 mL of NaOH from the buret. When the pH stabilizes, press *TRIGGER* and enter the current buret reading (approximately 2.0 mL). You have now entered the second data pair.

14. Continue to add 2.0 mL increments, entering the buret level after each increment. When the pH has leveled off between 10.5 and 11, select 2 STOP AND GRAPH.

15. Examine the data points along the displayed graph of pH vs. mL of NaOH. Volume is on the x-axis and pH is on the y-axis. To determine the equivalence point (where H+ion concentration equals OH-1 ion) go to the region of the graph with the large increase in pH. Examine the data to find the largest increase in pH upon the addition of 2 mL of NaOH solution. Record the NaOH volume just BEFORE this jump. Record the NaOH volume after the AFTER the largest pH increases was observed.

16. Press 2 YES to repeat the data collection. Press *ENTER*. The pH data in List 2 will automatically be transferred to List 4. This temporarily stores your lemonade data so it can be graphed and analyzed along with the data you collect with the next drink or citric acid. Dispose of the beaker contents as directed by your teacher.

17. Repeat the procedure for the citric acid starting with Step 2 in 16.

18. PRESS ENTER then select NO when asked if you want to repeat the trial.
Select QUIT from the MAIN MENU.

19. Set up the data for viewing the two curves on the same graph.

- To set up the graph for citric acid solution, press *2nd* [STAT PLOT], then Plot 1. Use the arrow keys and press ENTER to select any of the settings you change. The settings should be: Plot1 = On, Type =, Xlist = L1, Ylist = L2, and
Mark = a dotTo set up the graph for the lemonade drink on the same graph, press *2nd*[STAT PLOT], then Plot 2. Follow the directions for plot 1 and change the Ylist to L4.

- To set the scaling and increments for each axis, press *window*. Scale volume of NaOH (X) from 0 mL to the maximum volume with increments of 10 mL.
- In the same manner, scale pH (Y) from 0 to 14 with increments of 1 pH unit. Press *GRAPH* to view the graph. Two curves should be acid solution and one for the lemonade drink.displayed, one for the citric
- Use the TI-Graph Link cable and program to transfer the graph of pH vs. volume to a compatible computer. Label each curve as buffered lemonade or unbuffered citric acid.

20. REPEAT the experiment substituting fruit drink 2 and fruit drink 3.

Assessment:

Before data collection, students need to be familiar with writing buffer equations for weak acids and their bases. A review of how to prepare buffer solutions and calculate their pH would be helpful for advanced students. After data collection, students may be asked to graph by hand one of the sets of data, i.e., lemonade vs citric acid.

One assessment may be to give the students sample data and let them graph it on the calculator. During the second part of this activity, students collect pooled data and construct a scatter plot transferring data from the calculator to the worksheet. The teacher may assess the accuracy, appropriate labeling, and pattern.

Extension/Follow Up:

- Students could test the buffering capacity of a body of water in their area. This could be linked to a discussion on acid rain.
- Students could have a more detailed discussion on the significance of multiple trials versus pooled group data. Statistical analyses including measures of central tendency and dispersion may be included.
- Students could research the use of buffers in living systems.

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